PATENT SPECIFICATION

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PROVISIONAL SPECIFICATION

Improvements relating to the Heat-Treatment of Metal Articles

We, MORRIS MOTORS LIMITED, a Company incorporated under the Laws of Great Britain, of Engines Branch, Courthouse Green, Coventry, in the County of Warwick, JOHN HENRY BRIDLE and ROBERT JAMES BROWN, both British Subjects, of the Company's address, do hereby declare the nature of this invention to be as follows:—

This invention relates to the heat-treatment of metal articles, and is especially concerned with improvements in contour heating and surface hardening of articles having a contour which varies abruptly, due to local prominences or depressions, such as, for example, toothed gears, and shafts provided with splines or key-ways.

High-frequency induction heating of metal articles, followed by quenching, affords a convenient and rapid method of producing surface hardening but, up to the present, so far as is known, no way has been found of obtaining completely satisfactory results with it in the case of articles of the character specified above. For example, when applied to gear teeth, the method in question as practised hitherto has proved incapable of affording sufficient uniformity of the depth of skin-hardening at the tips, flanks and roots of the teeth; the depth of hardening at the roots, namely along the portion which unites adjoining teeth, always being much less than that produced at the tips and flanks. This serious drawback is attributable to the contour heating being non-uniform because, owing to the considerable temperature gradient between the heated surface and the relatively cool interior of the gear, the rate of transfer of heat inwardly by thermal conduction is much greater at the roots than at the flanks and tips of the teeth.

The present invention aims at making it possible to effect substantially uniform contour heating of articles having an abruptly varying contour, and thereby to bring about correspondingly uniform contour hardening. This is achieved, according to the invention, by heating for a short period the surface layers of the article to be treated, thereafter allowing the surface heat to soak into the mass of the article, and then reheating for a very brief period followed immediately by quenching. The initial pre-heating, followed by the soaking stage, serves to reduce materially the temperature gradient between the surface layers and the main mass by the time the final reheating occurs, and, as a consequence, substantially uniform contour heating is achieved in the final stage, leading to the formation of a hard skin of correspondingly uniform thickness.

Although the whole process may conveniently be carried out by high-frequency induction heating, the pre-heating operation may be performed in other ways, if desired, for example by using a furnace or by means of electrical resistance heating at a low frequency such as 50 cycles per second. In some cases, however, the pre-heating may have to be carried out in two or more stages in order to obviate risk of fusing the surface of the specimen.

In the preferred method of carrying the invention into effect, the specimen to be treated is mounted centrally within a single-turn inductor having an axial width corresponding to that of the specimen. This inductor is used in conjunction with a "concentrator" consisting of a high-frequency transformer designed for use with the particular specimen concerned, and the heat-treatment process consists of the following sequence of operations.

First, the high-frequency current is switched on for a short period thus rapidly heating the surface layers of the

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specimen. The current is then switched off for a time sufficient to allow the surface heat to soak into the mass of the specimen. After this soaking period the current is again switched on for a very brief period to reheat the surface layers, and then the specimen is immediately quenched. The quenching operation may be conducted either by flooding the specimen with a quenching medium, such as water, or by dropping it into a bath of quenching medium located directly beneath the inductor.

The various operations are controlled by precision time-switch mechanism, which may need to be accurate to one-twentieth of a second, so arranged that the high-frequency current is switched on and off in accordance with the desired sequence of operations. Also, provision is made for automatically initiating the quenching operation immediately upon termination of the final stage of heating.

As an example, in an experiment made with the present invention on a toothed gear having an outside diameter of 1⅝ inches, an axial length of half an inch, nine teeth of twelve pitch, and a superficial area of 2.5 square inches, the duration of the pre-heating was 0.7 second, that of the soaking period one second, and that of the final reheating 0.35 second. The power employed was 14 kilo-watts, and the frequency 400 kilo-cycles. Subsequent examination of the specimen showed that the process successfully achieves substantially uniform contour hardening, a continuous hard skin of practically constant depth having been produced at the flanks, tips and roots of the teeth.

The use of the concentrator referred to above, although beneficial in some cases, is not essential and, if desired, this device may be omitted.

Dated this 26th day of February, 1946.
For the Applicants,
A. H. STEED.
Chartered Patent Agent.

COMPLETE SPECIFICATION

Improvements relating to the Heat-Treatment of Metal Articles

We, MORRIS MOTORS LIMITED, a Company incorporated under the Laws of Great Britain, of Engines Branch, Courthouse Green, Coventry, in the County of Warwick, JOHN HENRY BRIDLE, and ROBERT JAMES BROWN, both British Subjects, of the Company's address, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention relates to the heat-treatment of metal articles, and is especially concerned with improvements in contour heating and surface hardening of articles having a contour which varies abruptly, due to local prominences or depressions, such as, for example, toothed gears, and shafts provided with splines or key-ways.

High-frequency induction heating of metal articles, followed by quenching, affords a convenient and rapid method of producing surface hardening but, up to the present, so far as is known, no way has been found of obtaining completely satisfactory results with it in the case of articles of the character specified above. For example, when applied to gear teeth, the method in question as practised hitherto has proved incapable of affording sufficient uniformity of the depth of skin-hardening at the tips, flanks and roots of the teeth; the depth of hardening at the roots, namely along the portion which unites adjoining teeth, always being much less than that produced at the tips and flanks. This serious drawback is attributable to the contour heating being non-uniform because, owing to the considerable temperature gradient between the heated surface and the relatively cool interior of the gear, the rate of transfer of heat inwardly by thermal conduction is much greater at the roots than at the flanks and tips of the teeth.

The present invention aims at making it possible to effect substantially uniform contour heating of articles having an abruptly varying contour, and thereby to bring about correspondingly uniform contour hardening. This is achieved, according to the invention, by pre-heating for a short period the surface layers of the article to be treated, thereafter allowing the surface heat to soak into the mass of the article, and then re-heating the surface layers for a very brief period followed immediately by quenching. The initial pre-heating, followed by the soaking stage, serves to reduce materially the temperature gradient between the surface layers and the main mass by the time the final

reheating occurs, and, as a consequence, substantially uniform contour heating is achieved in the final stage, leading to the formation of a hard skin of correspondingly uniform thickness.

The whole process may conveniently be carried out by high-frequency induction heating, the duration of the pre-heating being restricted and the heat developed in the surface layers being allowed to diffuse uniformly throughout the mass of the work-piece before the reheating of its skin takes place. If desired, however, the pre-heating operation may be performed in other ways, for example by using a separate furnace of normal construction, or by means of electrical resistance heating at a low frequency such as 50 cycles per second, or by induction heating at a frequency lower than that employed for the final skin-heating. In some cases, however, the pre-heating may have to be carried out in two or more stages in order to obviate risk of fusing the surface of the specimen.

The preferred form of apparatus for carrying out the invention comprises a single-turn inductor mounted adjacent a quenching device, means for accurately locating the article to be treated coaxially within the inductor, a solenoid-operated valve controlling the supply of water or other liquid quenchant to the quenching device, and a time-switch mechanism which, after the surface layers of the article have been pre-heated and the surface heat has been allowed to diffuse throughout the mass of the article, effects the application of high-frequency current to the inductor for a very brief period, namely a fraction of a second, and immediately afterwards causes the valve to open so that the article is quenched.

The invention will now be described by way of example with reference to the accompanying diagrammatic drawing which illustrates the preferred manner of carrying the invention into effect.

The arrangement, shown as a central vertical section at the upper part of the drawing, includes a single-turn inductor which is formed from a copper plate A, having a central circular opening B from one side of which there is a gap (not shown) extending to the corresponding edge of the plate. This inductor surmounts an annular quenching chamber C the outer wall of which is formed by a cylindrical ring D of insulating material, such as that sold under the Registered Trade Mark "Tufnol." The ring D is firmly clamped between the inductor A and an insulating base plate E by bolts F. A vertical arbor G is screwed into the base plate E so as to extend centrally within the inductor opening B; and an insulating bushing H, the upper end of which is of reduced diameter, is fitted to the arbor to provide a support for the work-piece which, in the particular example under consideration, is a gear-wheel I. The arrangement is such that the work-piece is accurately located so as to be mounted co-axially within the inductor opening B, with the minimum practicable clearance, and the upper and lower faces of the inductor plate A are respectively co-planar with the corresponding faces of the work-piece.

In addition to being supported by the insulating bushing H, the work-piece I rests on a contact block J consisting of a thick chamfered ring of copper. A similar contact block K is placed on top of the work-piece, and the assembly is held together firmly by a clamping nut L on the arbor G.

The various operations are controlled by precision time-switch mechanism M comprising three stationary segmental contacts N, O and P, and a co-operating rotary wiper Q which is arranged to be driven by a synchronous motor (not shown) in the direction of the arrow. An alternating current supply of low frequency is connected to the terminals R and, when this supply is switched on, the wiper Q is set in rotation and first engages the contact N. This energises a low-frequency power transformer S, the secondary of which supplies current at 50 cycles per second to the contact blocks J, K, thus pre-heating the work-piece I, the connection to the lower contact block J being effected by means of a copper rod T which is screwed into it.

The pre-heating current is automatically switched off through a relay (not shown) when the wiper Q leaves the contact N, and, during the time that the wiper Q is travelling from the contact N to the contact O, the surface heat generated in the work-piece soaks into the mass of the latter. Upon the wiper Q meeting the contact O, a high-frequency generator U, which includes a high-frequency power transformer, is energised by actuation of a relay (not shown) and the output of this transformer is connected at V across the gap in the inductor A, whereby the surface layers of the teeth of the gear-wheel I are reheated.

Immediately after leaving the contact O and thereby switching off the high-frequency heating current, the wiper Q

engages the contact P and effects opening of a solenoid-operated valve W by way of which water is supplied to a ring-shaped header X. This is fitted with a number of small jets Y distributed uniformly around its top and extending through the base plate E into the quenching chamber C. The latter also contains an overflow pipe Z by means of which the water supplied to the quenching chamber is normally retained at given level. As a result of this, the time lag between cessation of the final skin-heating and application of the quench is reduced owing to the fact that, when the valve W is opened, the water which gushes from the jets Y only has to fill a comparatively small volume before the work-piece becomes flooded.

After the work-piece has been quenched the clamping nut L and the contact block K are removed in order to enable the work-piece to be replaced by a fresh one.

Provision is made for adjusting the relative positions of the stationary contacts of the time switch mechanism M so that, for example, the duration of the soaking period between the pre-heating and the final skin-heating may readily be varied to suit requirements.

As an example, in an experiment made with the present invention on a toothed gear having an outside diameter of 1¼ inches, an axial length of half an inch, nine teeth of twelve pitch, and a superficial area of 2.5 square inches, the duration of the pre-heating was 0.7 second, that of the soaking period one second, and that of the final reheating 0.35 second. The power employed was 14 kilo-watts, and the frequency 400 kilo-cycles for both of the heating operations. Subsequent examination of the specimen showed that the process successfully achieves substantially uniform contour hardening, a continuous hard skin of practically constant depth having been produced at the flanks, tips and roots of the gear teeth.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is:—

1. The method of effecting surface hardening of metal articles which comprises pre-heating for a short period the surface layers of the article to be treated, thereafter allowing the surface heat to soak into the mass of the article, and then reheating the surface layers for a very brief period followed immediately by quenching.

2. The method of effecting surface hardening of metal articles according to claim 1, wherein the two heating operations are both effected by high-frequency induction heating.

3. The method of effecting surface hardening of metal articles according to claim 1, wherein the pre-heating is effected by alternating current of a frequency lower than that employed for the reheating.

4. Apparatus for effecting surface hardening of metal articles, comprising a single turn inductor mounted adjacent a quenching device, means for accurately locating the article to be treated co-axially within the inductor, a solenoid-operated valve controlling the supply of water or other liquid quenchant to the quenching device, and a time-switch mechanism which, after the surface layers of the article have been pre-heated and the surface heat has been allowed to diffuse throughout the mass of the article, effects the application of high-frequency current to the inductor for a very brief period and immediately afterwards causes the valve to open so that the article is quenched.

5. Apparatus according to claim 4, in which the pre-heating of the article is effected by clamping it between contact blocks to which low-frequency current is supplied.

6. The method of effecting surface hardening of metal articles having an abruptly varying contour, substantially as described with reference to the accompanying drawing.

Dated this 27th day of February, 1947.
For the Applicants:
A. H. STEED,
Chartered Patent Agent.

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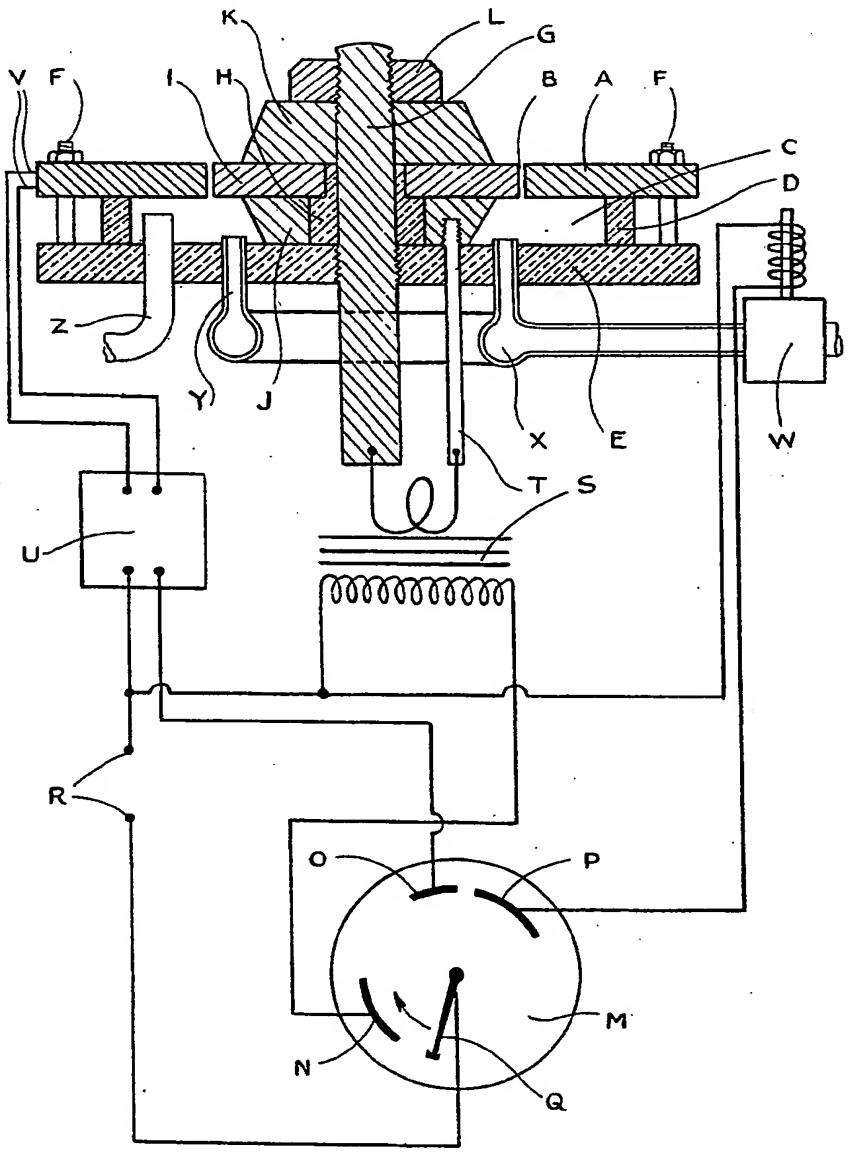

[This Drawing is a reproduction of the Original on a reduced scale.]

H.M.S.O. (Ty. P.)